

Dominant mode in the cuprates: electronic vs. phononic scenario

George Kastρινakis

*Institute for Electronic Structure and Laser (IESL), Foundation for Research and Technology - Hellas (FORTH),
P.O. Box 1527, Iraklio, Crete 71110, Greece **
(February 4, 2002)

We make the case for an electronic origin of the strong mode, recently seen in ARPES experiments, and, in this regard, further discuss the physics of the spin resonance peak.

Recent ARPES experiments observe a 'kink' in the energy vs. momentum dispersion, in a number of cuprates - e.g. see¹⁻³. The effect is more intense in the superconducting state, but clearly persists in the normal state as well. Moreover, optical conductivity experiments indicate a matching reduction of the scattering rate⁴.

It is well known that a sharp collective mode can generate an electronic response^{5,6} in qualitative agreement with the aforementioned data. The nature of this sharp mode, i.e. electronic, phononic etc. origin, does not influence qualitatively the effect.

Refs.^{1,2} take the viewpoint that the dominant mode coupled to the carriers is of phononic origin. Below we argue for an electronic dominant mode picture.

As stated in^{3,2}, the well known spin resonance peak could, in principle, be interpreted as the sharp mode. It is dismissed, afterall, on the basis that, *usually*, the spin resonance peak is not seen in the normal state.

In ref.⁷ we have presented a model for the spin resonance peak, which can consistently account for its appearance in the *normal* state of Zn-doped YBCO⁸. The central idea here is that the spin resonance peak - or some equivalent mode - is a many-body effect, present for *all* temperatures, and for a fairly broad range of parameters. The peak just becomes *sharper* in the superconducting state, once the characteristic energy scale $\omega_{res} < 2\Delta$, where Δ is the (maximum) gap - e.g. c.f.⁶. This fact can explain why the peak is visible by neutron scattering only in the SC state of the pure YBCO and BSCCO. Both these materials are bilayers, and in ref.⁷ a specific bilayer (easily extendable to multi-layer: e.g. for a tri-layer system, *two* resonance peaks could appear) model is proposed. However, the dominant peak in the susceptibility of the carriers is of course present even for a monolayer system. In general, a non-parabolic dispersion, such as the t, t', t'', \dots used for the cuprates, generates peaks in the susceptibility for various momenta and energies, as a function of the filling factor and the coupling - e.g. c.f.^{9,7}. These peaks can be both strong and narrow. In the frame of a self-consistent Hubbard model calculation, we obtain values for ω_{res} in the range $t/5$ to $t/13$ for $U \sim 4t - 6t$.

Besides the purely electronic contribution, the peak(s) can have a magnetic component according to the model in⁷, which can make the peaks even better defined. As mentioned in⁷, Zn-doping does increase the strength of the susceptibility peak, due to the AF correlations enhancement. We expect that Zn-doping can make observable the peak in materials where it is only seen in the SC state, in the same manner as in YBCO. Actually, in principle it is possible that Zn-doping may enhance the peak to the point of it becoming detectable even for materials such as LSCO, in which it is not detectable even in the SC state.

There are two very recent expts. agreeing with the above. First, in¹⁰ it was shown that the famous ARPES feature is not of phononic origin (but of rather electronic), via reflectivity measurements. Second, in¹¹ the monolayer Tl-2201 was shown to exhibit the spin resonance peak in the SC state.

Thus it appears that the electronic (possibly enhanced by magnetism) scenario provides a viable explanation for the 'kink' feature seen in ARPES, in agreement with the spin resonance peak observations.

* e-mail: kast@iesl.forth.gr

¹ A. Lanzara et al., Nature **412**, 510 (2001).

² Z.X. Shen, A. Lanzara, S. Ishihara, N.Nagaosa, cond-mat/0108381.

³ P.V. Bogdanov et al., Phys. Rev. Lett. **85**, 2581 (2000).

⁴ T. Timusk, B.W. Statt, Repts. Prog. Phys. **62**, 61 (1999).

⁵ S. Engelsberg, J.R. Schrieffer, Phys. Rev. **131**, 993 (1963).

- ⁶ M.R. Norman, H. Ding, Phys. Rev. B **57**, R11089 (1998).
- ⁷ G. Kastinakis, Physica C **340**, 119 (2000); v2 of cond-mat/0005485.
- ⁸ H.F. Fong et al., Phys. Rev. Lett. **82**, 1939 (1999).
- ⁹ C.-H. Pao, N.E. Bickers, Phys. Rev. B **51**, 16310 (1995).
- ¹⁰ N.L. Wang et al., cond-mat/0201484.
- ¹¹ H. He et al., cond-mat/0201252, to appear in Science.